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ATOM INTERFEROMETRY PROGRESS

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Office of Naval Research Contract N00014-89-J-1207

We are constructing an atom interferometer, in which the atom waves are physically separated prior to being recombined. ~~We are using~~ fabricated transmission gratings as optical elements for the matter waves. Atom interferometers should be useful in studies of atomic properties, tests of basic quantum physics, for metrology, as rotation sensors, and perhaps ultimately as devices to make ultra-small structures using atom holograms.

During the last year our atom interferometer has evolved from a rough plan to an essentially complete device. At present all the major components of the interferometer have been built, and tested at least once. ~~We shall give~~ the system its first real try in the next year. Our interferometer consists of three 0.2 μm - period diffraction gratings equally spaced ~ 0.65 m apart in our atomic beam machine. The maximum separation of the beams will be ~ 60 μm. The first two gratings separate and redirect the atomic beam forming a standing wave interference pattern in the atomic flux at the third grating, which acts like a mask to sample this pattern. A principal technical obstacle is the mechanical vibrations of our machine which will blur the interference pattern.

Our anticipated final signal strength may be estimated from the properties of the individual gratings. Attenuation caused by the primary grating and the grating support structure gives an intensity in the 0^{th} order of ~ 1/8 of the incident intensity, and 1/16 in each of the ± 1 orders. The final intensity detected at the maximum of a fringe after

transmission through all three gratings may be calculated by summing the amplitudes for the two sides of the interferometer, and will be 0.005 of the incident intensity. The fringe contrast will be 4 to 1, so the interference signal will be 0.004 of the incident intensity. The final interference signal through the interferometer is anticipated to be $\sim 4 \times 10^3$ counts per second. This should generously exceed the noise of the detector ($\leq 100\,\mathrm{sec}^{-1}$).

The required limits on vibrations are of two types: The first is that the three gratings move relative to each other by less than ~ 1/4 period (50 nm) during the time the final grating samples the intensity at a given position. Thus, the rms amplitude of relative vibrations integrated over all frequencies greater than the reciprocal of the integration time must be less than ~ 50 nm. The second requirement is on motion of the gratings due to acceleration of, or rotation about, the center of mass of the grating system during the 1.3 ms time it takes for the atoms to traverse the interferometer. This means that below ~ 900 Hz the rms acceleration must be less than $10^{-2} ms^{-2}$, and the rms angular velocity must be less than 10^{-5} radians per second.

We solved our vibration problem using a combination of passive isolation and active feedback. The passive isolation system consists of small pneumatic feet which act like damped springs to support the machine and give it a 3 Hz resonant frequency. This isolates it from building noise at higher frequencies. The active feedback system is used to stabilize the relative positions of the three gratings at frequencies below ~ 150 Hz. This system works best at low frequencies (< 10 Hz) where the passive system is least effective. The reduction of relative motion provided by the active system will allow us to use much longer integration times when we are looking for the interference signal. The active feedback system uses a laser interferometer which has the same transmission

grating geometry as the atom interferometer. The gratings for the optical interferometer are mounted on the same three translation stages as the matter wave gratings in order to record the exact relative orientation of the matter wave interferometer. The signal from the optical interferometer which provides a measure of the relative alignment of the three grating platforms is applied to a Piezo-electric translator (PZT) through a feedback network in order to stabilize the platforms (Fig. 1). Using this system we have reduced the relative rms motion (at frequencies less than 0.3 Hz) of the gratings from ~ 1500 to 40 nm which is adequate. The rms acceleration in a frequency range to which the interferometer is sensitive was reduced from 1.1×10^{-2} to $2.3 \times 10^{-3} ms^{-2}$ which is safe by a factor ~ 5 and also assures sufficiently low angular velocities of the apparatus.

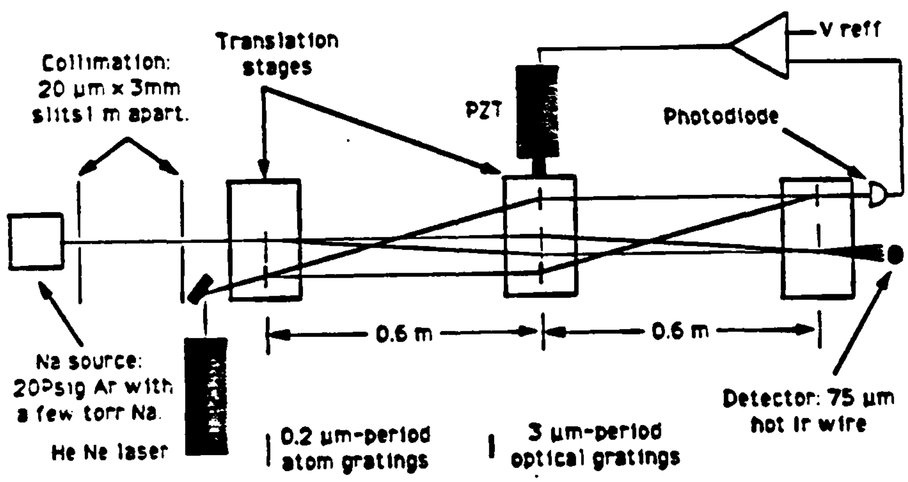

Figure 1: Our current atom interferometer with laser interferometer vibration isolation system shown. Not to scale.

We have also made significant progress on overcoming another technical obstacle, the relative alignment of the atom gratings. In order that all points along the height (3mm) of our ribbon shaped beam have the same phase of interference signal it is

necessary that the gratings be aligned with respect to rotations about the beam axis to an angle of ~ 10^{-5} rads. We accomplished this by using a technique based on the optical polarizing properties of the gratings.

Aside from the work on vibrations and alignment mentioned above, the main progress in the last year has been the construction of the various mechanical components that position the gratings inside the vacuum envelope. In addition we have written computer software, and built electronic hardware to control the position to the three grating platforms, the detector, and the height, angle, and position of the second collimating slit. Instead of directly varying the voltage of the PZT that controls the position of the last grating, we will now be using the computer to vary the null point of the active feedback system when we search for interference fringes.

When we have successfully demonstrated this interferometer our first experimental objective will probably be a demonstration of Berry's phase with bosons. Another possibility would be an improved measurement of the Aharonov - Casher effect.

RECENT PUBLICATION

Atom Optics, David W. Keith and David E. Pritchard, New frontiers in QED and Quantumoptics, (Plenum Press, New York) to be published. NATO Advance Study Institute, Istanbul, Turkey (1989).

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